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Potential of Solar Energy Harvesting in Ulu Pauh, Perlis, Malaysia using Solar Radiation – Analysis Studies

Syafawati A.N.*, I. Daut, M. Irwanto, Z. Farhana, N. Razliana, Arizadayana Z., S.S. Shema

Electrical Energy and Industrial Electronic Systems Reseach Cluster, School of Electrical Systems Engineering, Universiti Malaysia Perlis, Jalan Pengkalam Assam, 01000 Kangar, Perlis, Malaysia

Abstract

This paper presents analysis studies of solar energy harvesting potential in Ulu Pauh, Perlis, Malaysia which located at 6.462°N, 100.351°E. Solar radiation is radiant energy received from the sun, from both direct and diffuse or reflected sunlight. In average of the year, Perlis able to receive about half day of solar radiation regardless the reflectivity. Perlis is northern state of Peninsular Malaysia and known as hottest state in Malaysia with the average 12 hours of sunlight received per day. The discussion in this paper also includes several factor and parameter in the solar energy collecting potential analysis. The analysis studies had updated for last six month in year 2011. The potential of receiving solar radiation at 6.462°N, 100.351°E is compared to 6.431°N, 100.185°E with support by recorded data using Davis Vantage Pro2 Weather Station. All the data used in this paper are live record for the past six month which used for ongoing research on solar and wind energy.

Keywords: Solar Energy; Energy Harvesting; Solar Radiation

1. Introduction

Tiwari G.N. says that "sun is the primary source of all renewable energy resources. The technologies based on solar energy are eco-friendly with environment" and "for global balancing act of ecosystem; everyone should be encouraged to use renewable energy technology to meet their energy requirement" [1]. Currently many researches begin upgrading all the technologies to fulfill these two clauses. As a

* * Corresponding author. Tel.: +6-017-721-0702; fax: +6-04-979-8903.
E-mail address: syafawati@unimap.edu.my

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developing countries, Malaysia are not left behind in develop the renewable energy which become main issues in alternative energy. Unlike others source of renewable energy, solar energy are most highlight in Malaysia even though field are limited. This is because of location of Malaysia at equator has become factor to harvest the solar energy.

Nomenclature

a, b	constants obtained for a particular location
H_0	daily solar radiation on a horizontal surface at a location (MJm^{-2})
I_0	daily solar radiation on horizontal surface (MJm^{-2})
I_{sc}	solar constant (Wm^{-2})

Greek symbols

β	slope angle (°)
δ	declination angle (°)
□	latitude angle (°)
γ	surface azimuth angle (°)
θ_z	angle of incidence on a horizontal surface
ω	hour angle (°)
ω_s	sunset hour angle (°)
α	altitude (°)

2. Data and Method

2.1. Solar Radiation

The solar irradiance (H_0 in W/m^2) is the power density incident on an object due to illumination from the sun. At some distance from the sun, the total power from the sun is spread out over a larger surface area and therefore the solar irradiance on an object in space decreases as the coordinate of the object. The actual power density varies slightly since the Earth-Sun distance changes as the movement of Earth orbiting the sun in elliptical. The radiation at the Earth's surface widely varies while the solar radiation incident on the Earth's atmosphere is relatively constant. The radiation is varies due to atmosphere effects, local variations in the atmosphere, latitude of the location and season of the year and time of day [2].

2.2. Sun-Earth Angles

The energy flux of beam radiation in a surface with arbitrary orientation can be obtained from the knowledge of flux either on a surface perpendicular to the sun rays or on horizontal surface. If θ be the

angle of incidence of a beam of flux *I*, incident on a plane surface the flux incident on the plane surface is *I cos* θ as illustrated in Fig. 1 below [1]:

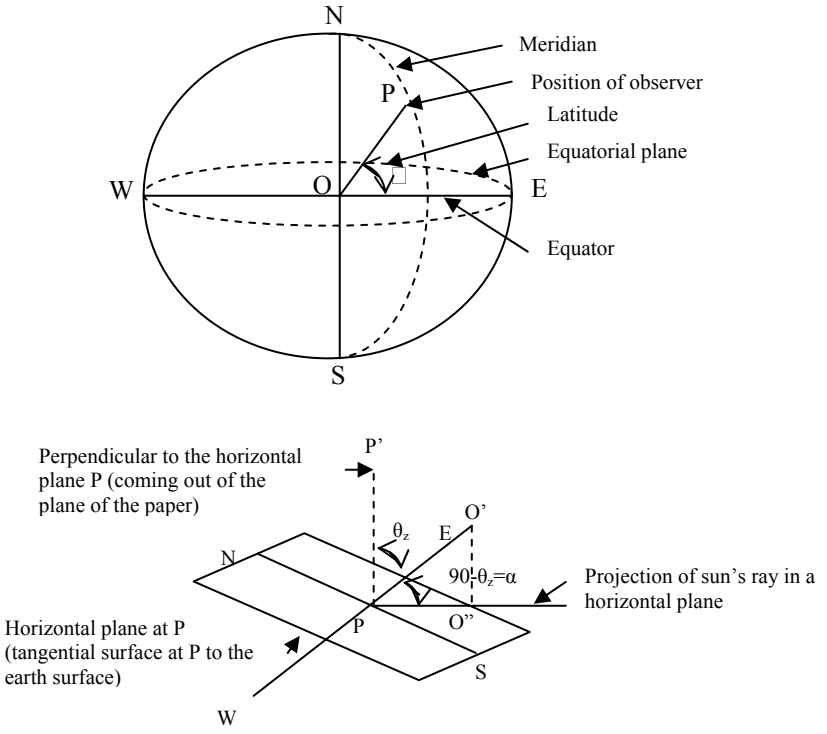

Fig. 1 View of different angles.

Latitude, □ of location is the angle made by the radial line. Declination angle, δ defined as the angle between the line joining the centers of the sun and the earth and its projection on the equatorial plane. This angle is variance with *n*th day of year as in equation 1 below:

$$\delta = 23.45 \sin\left[\frac{360}{365}(284+n)\right] \quad (1)$$

Hour angle, ω is the angle through which the earth must be rotated to bring meridian of the plane directly under the sun as shown in equation 2.

$$\omega = (ST - 12) \times 15° \quad (2)$$

While consider the hour angle, the sunset hour angle, ω_s is defined as:

$$\omega_s = \cos^{-1}(-\tan\phi \tan\delta) \quad (3)$$

Zenith angle, θ_z is the angle between sun's ray and perpendicular line to the horizontal plane as define in equation 4.

$$\cos\theta_z = \cos\phi\cos\delta\sin\omega_s + \left(\frac{2\pi\omega_s}{360}\right)\sin\phi\sin\delta \quad (4)$$

All the equation above is describe the angle as illustrate in Fig. 2 below. These angles are apply in the next section which discussed the analysis method to determine the solar radiation potential in Ulu Pauh, Perlis. All the calculation use is matched with latitude 6.462°N and recorded data from weather station located at EEIES research cluster with latitude 6.431°N.

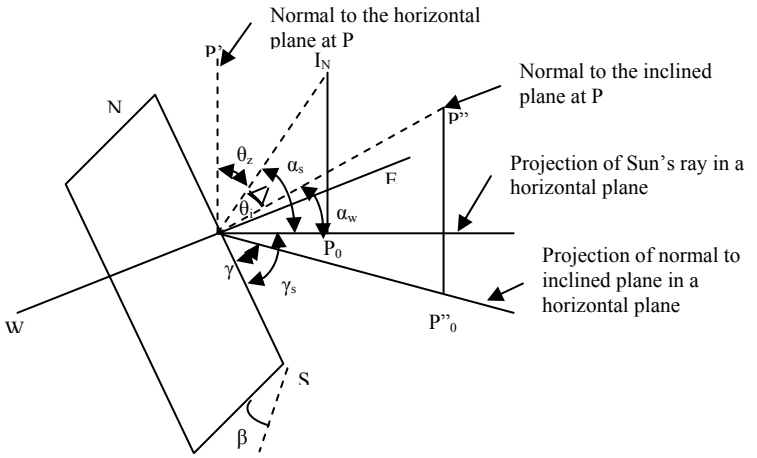

Fig.2. View of various sun-earth angles.

3. Analysis and Discussion

Collected solar energy at this location able to apply and implement as alternative source of the campus. Through this paper, the potential of using solar energy in the campus are discussed with applying estimation of solar radiation methods.

Solar radiation on horizontal surface is determined with correspond to the zenith angle and solar hour. From the equation 2, Perlis stated that almost 12 hours per day received the sun light in a year. At any point of time, the solar radiation outside the atmosphere (I_0) incident on a horizontal plane is

$$I_0 = I_{sc}\left[1.0 + 0.033\cos\left(\frac{360n}{365}\right)\right]\cos\theta_z \quad (5)$$

where I_{sc} is the solar constant and n is the day of the year.

It is often required to have the integrated daily extraterrestrial radiation on a horizontal surface, H_0 for the calculation of daily solar radiation as shown in equation 6:

$$H_0 = \frac{24\times 3600}{\pi} I_0 \quad (6)$$

Some research work had used Hargreaves method and Hargreaves Samani method in determine the solar radiation. However, the potential of solar radiation in Perlis had studied and discussed in technical paper [3-4]. From the previous discussion, authors are highly recommended and suggest that Perlis is has potential in solar radiation.

In this paper, the location in Perlis has chosen which is at Ulu Pauh. Several factors and parameters are considered such as the geometrical, latitude, longitude and size of field area. The analysis of the graph shows in this section is discussed about the solar radiation and its potential at this location.

Fig.3 shows solar radiation which correspond with the temperature. The data is recorded from March until August of year 2011. The climate changes and monsoon are the factors that effect the actual solar radiation due to estimation of solar radiation state by Hargreaves method.

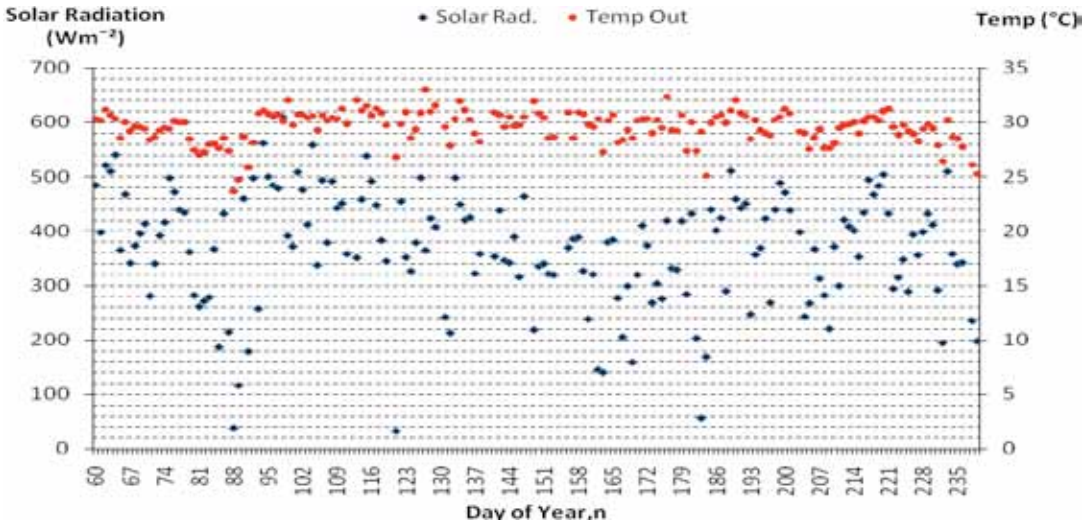

Fig.3. Relationship of temperature and solar radiation record by weather station

From the data collected, Fig.3 shows the compilation result of solar radiation for the last six month. The graph proved that majority solar radiation falls in the range six month are above 350 Wm^{-2}. Almost 95% of the days in the monitoring period are received about 40-70% of full sun radiation.

Even thought the solar radiation in this period are not collected more than 70% of full radiation, this is because of the declination angle and position of observed location of the year. The detail discussion is show in Fig.4 below, where the declination angle and sunset hour had changes through the year. From the Fig.4 show that solar radiation falls in the period range is change from maximum to minimum slope. At 95^{th} day of the year, the solar radiation start to decrease to the minimum until it reaches at 172th day of year.

While the solar radiation curve decreasing, the number of daylight is increasing from 12.0 hours per day to 12.4 hours per day. The small changes in number of daylight had helps the days to received longer hours of sun light per day. That is result that recorded and monitored by the weather station to received total of solar energy in a day.

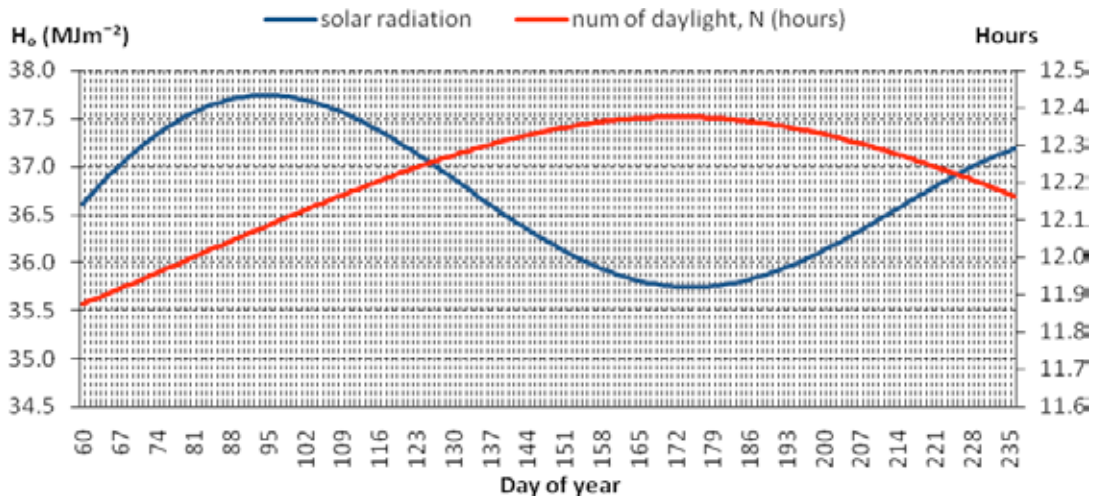

Fig.4. Solar radiation with number of daylight at Ulu Pauh

4. Conclusion

From the overall of the observation and discussion, this paper concludes that Ulu Pauh is known as potential area to harvest the solar energy. This is support by the methods applied in the equation and data collected from the weather station. Some parameter and modification are needed to take into account for detailed before it develops as solar energy harvesting center in Perlis. However, the research on solar energy is continuously and develops for further improvement and analysis.

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